ENGINEERING PRINCIPLES®

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July 11, 2018

James A. Jennings
Jennings Teague, P.C.
204 N. Robinson, Suite 1000
Oklahoma City, Oklahoma 73102

Re: Faust v. Autoliv

Dear Mr. Jennings,

Following your request, Engineering Principles®, LLC has performed certain investigations regarding the motor vehicle collision at issue in the Faust matter. The purpose of this letter is to report the results of my investigations to date. In general, I anticipate offering testimony in the areas of mechanical engineering and the design, operation, usage, the performance of occupant protection systems and the role of a component supplier. Engineering Principles, LLC bills $550 per hour for my consulting services.

QUALIFICATIONS AND METHODOLOGY

My expertise is in the discipline of mechanical engineering, including the fields of occupant crash protection, accident reconstruction, mechanics, materials, design and the interaction between a component supplier and a vehicle manufacturer. I have extensive experience evaluating the performance of occupant protection systems including, but not limited to, seat belts, airbags, seats, child restraint systems, and the crashworthiness of motor vehicles. I have conducted over one hundred full-scale vehicle crash tests and sled tests and reviewed thousands of additional crash and sled tests. I have evaluated and tested over one thousand seat belts and have investigated hundreds of motor vehicle collisions. My research addresses occupant protection, occupant kinematics, accident reconstruction, mechanics, material selection, and the deformation, fatigue and fracture of materials.

I have a Ph.D. in Mechanical Engineering from the Massachusetts Institute of Technology, an M.S. in Mechanical Engineering from the University of Illinois at Urbana-Champaign, and a B.S. in Mechanical Engineering from the University of Arizona. As a graduate student, I have taught mechanics and materials at the University of Illinois at Urbana-Champaign. I am a NHTSA-certified Child Passenger Safety Technician. I have successfully completed a Traffic Accident Reconstruction Training course at Northwestern University.

The generally-accepted methodology for evaluating the design, safety and performance of occupant restraint systems includes analysis of factors and background such as dynamic testing, government standards, peer products, industry practices, field performance and

EXHIBIT
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technical work published in the literature, particularly as of the time a product is designed. In addition, the benefits and drawbacks of designs in real-world applications should be considered. For this matter, I have evaluated the forensic evidence, available test data and literature, carefully considered all reasonable hypotheses, considered plaintiff expert theories, and conducted an exemplar surrogate study to reach my opinions and conclusions. This is the same methodology used by myself for previous matters and by other experts and knowledgeable persons in the field of occupant protection research. Appendix A includes a list of materials that I have reviewed as part of my investigation.

SUBJECT COLLISION

A 2012 Chevrolet Malibu with two occupants, Ashley and [redacted] [redacted], drifted off the road and struck a tree. From the event data recorder (EDR) report and from Mr. Jon Bready's accident reconstruction, the Malibu struck the tree at a speed in excess of 60 mph. The delta-V was also in excess of 60 mph. The EDR shows both the driver and right-front passenger positions as buckled.

EDR

Multiple Event Data

Associated Events Not Recorded	0
An Event(s) Preceded the Recorded Event(s)	No
An Event(s) was in Between the Recorded Event(s)	No
An Event(s) Followed the Recorded Event(s)	No
The Event(s) Not Recorded was a Deployment Event(s)	No
The Event(s) Not Recorded was a Non-Deployment Event(s)	No

System Status At AE

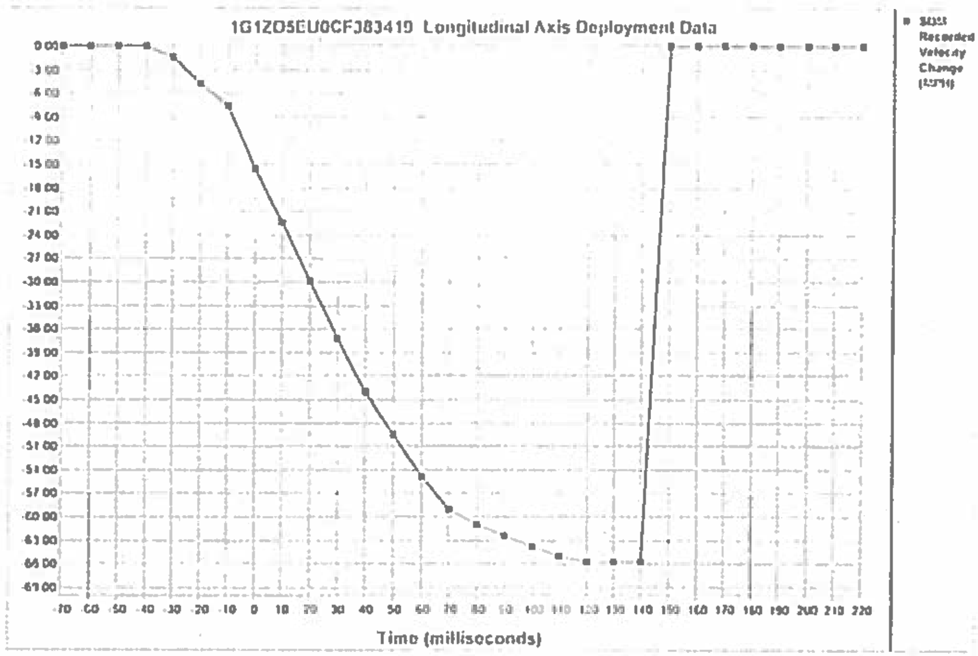
Vehicle Identification Number	**1ZD5EU*C*383419
Low Tire Pressure Warning Lamp (If Equipped)	OFF
Vehicle Power Mode Status	Run
Remote Start Status (If Equipped)	Inactive
Run/Crank Ignition Switch Logic Level	Active
Brake System Warning Lamp (If Equipped)	OFF

System Status At 1 second

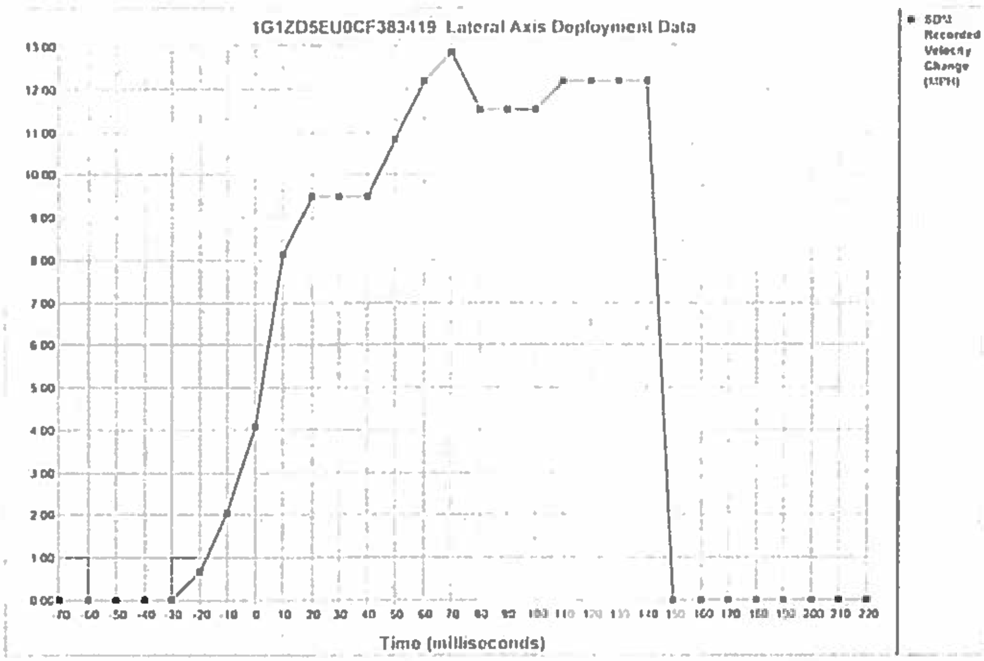
Transmission Range (If Equipped)	Sixth Gear
Transmission Selector Position (If Equipped)	Sixth Gear
Traction Control System Active (If Equipped)	No
Service Engine Soon (Non Emission Related) Lamp	OFF
Service Vehicle Soon Lamp	OFF
Outside Air Temperature (degrees F) (If Equipped)	59
Left Front Door Status (If Equipped)	Closed
Right Front Door Status (If Equipped)	Closed
Left Rear Door Status (If Equipped)	Unused
Right Rear Door Status (If Equipped)	Unused
Rear Door(s) Status (If Equipped)	Closed

System Status At Deployment

Ignition Cycles At Investigation	3761
SIR Warning Lamp Status	OFF
SIR Warning Lamp ON/OFF Time (seconds)	655200
Number of Ignition Cycles SIR Warning Lamp was ON/OFF Continuously	3760
Ignition Cycles At Event	3761
Ignition Cycles Since DTCs Were Last Cleared	254
Driver's Belt Switch Circuit Status	BUCKLED
Passenger Belt Switch Circuit Status (If Equipped)	BUCKLED
Diagnostic Trouble Code at Event Enable, fault number: 1	N/A
Diagnostic Trouble Code at Event Enable, fault number: 2	N/A
Diagnostic Trouble Code at Event Enable, fault number: 3	N/A
Diagnostic Trouble Code at Event Enable, fault number: 4	N/A
Diagnostic Trouble Code at Event Enable, fault number: 5	N/A
Diagnostic Trouble Code at Event Enable, fault number: 6	N/A
Automatic Passenger SIR Suppression System Validity Status at AE	Valid
Automatic Passenger SIR Suppression System Status at AE	Air Bag Suppressed
Automatic Passenger SIR Suppression System Validity Status at First Deployment Command	Valid
Automatic Passenger SIR Suppression System Status at First Deployment Command	Air Bag Suppressed
Driver 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	60
Driver 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	64
Passenger 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	Suppressed
Passenger 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	Suppressed
Driver Side or Roof Rail/Head Curtain Time From Algorithm Enable to Deployment Command Criteria Met (msec)	N/A
Passenger Side or Roof Rail/Head Curtain Time From Algorithm Enable to Deployment Command Criteria Met (msec)	N/A
Time Between Events (sec)	0
Driver First Stage Deployment Loop Commanded	Yes
Driver Second Stage Deployment Loop Commanded	Yes
Driver Side Deployment Loop Commanded	No
Driver Pretensioner Deployment Loop Commanded	Yes
Driver (Initiator 1) Roof Rail/Head Curtain Loop Commanded	No
Driver (Initiator 2) Roof Rail/Head Curtain Loop Commanded	No
Driver Knee Deployment Loop Commanded	No
Passenger First Stage Deployment Loop Commanded	No
Passenger Second Stage Deployment Loop Commanded	No
Passenger Side Deployment Loop Commanded	No
Passenger Pretensioner Deployment Loop Commanded	Yes
Passenger (Initiator 1) Roof Rail/Head Curtain Loop Commanded	No
Passenger (Initiator 2) Roof Rail/Head Curtain Loop Commanded	No
Passenger Knee Deployment Loop Commanded	No
Driver Anchor Pretensioner Deployment Loop Commanded (If Equipped)	No
Second Row Left Pretensioner Deployment Loop Commanded	No
Third Row Left Roof Rail/Head Curtain Loop Commanded	No
Passenger Anchor Pretensioner Deployment Loop Commanded (If Equipped)	No
Second Row Right Pretensioner Deployment Loop Commanded	No
Third Row Right Roof Rail/Head Curtain Loop Commanded	No
Second Row Center Pretensioner Deployment Loop Commanded	No
Driver 2nd Stage Deployment Loop Commanded for Disposal	No
Passenger 2nd Stage Deployment Loop Commanded for Disposal	No
Crash Record Locked	Yes
Vehicle Event Data (Pre-Crash) Associated With This Event	Yes
Deployment Event Recorded in the Non-Deployment Record	No
Event Recording Complete	Yes



Time (milliseconds)	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70
SDM Longitudinal Axis Recorded Velocity Change (MPH)	0.00	0.00	0.00	0.00	-1.36	-4.74	-7.45	-15.59	-22.36	-29.82	-37.27	-44.05	-49.47	-54.89	-58.96
Time (milliseconds)	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220
SDM Longitudinal Axis Recorded Velocity Change (MPH)	-60.99	-62.35	-63.70	-65.00	-65.74	-65.74	-65.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Time (milliseconds)	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70
SDM Lateral Axis Recorded Velocity Change (MPH)	0.00	0.00	0.00	0.00	0.00	0.68	2.01	4.07	8.13	9.49	9.49	9.49	10.84	12.20	12.88
Time (milliseconds)	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220
SDM Lateral Axis Recorded Velocity Change (MPH)	11.52	11.52	11.52	12.20	12.20	12.20	12.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VEHICLE INSPECTIONS AND PHYSICAL EVIDENCE

I inspected the subject vehicle on May 11, 2017. The vehicle is a 2012 Chevrolet Malibu. The vehicle has significant frontal damage. For the driver position, the webbing has been cut and has retracted behind the trim of the B-pillar. The latch plate is missing. There are clear load marks on the D-ring. The frontal driver airbag has deployed.

For the right-front passenger position, the webbing has been cut in two locations. The cut ends match up indicating that all of the webbing is present and accounted for. The seat-mounted outboard anchor (OBA) has a pretensioner which appears deployed (it appears retracted) (Figure 1). The latch plate was found latched in the buckle; the latch plate was removed, inspected and then latched in the buckle for safe-keeping. The cover on the latch plate is missing (Figure 2a). The latch plate is a locking latch plate design. There are load marks on the plastic clamping surface of the latch plate where it interacted with the webbing (Figures 2b-d).

There are load marks on the D-ring (Figure 3). There is what appears to be biological material deposited on the webbing (Figure 4). There is longitudinal folding of the webbing. In its current state, the retractor will not retract webbing or allow webbing to be extracted. There is plastic transferred to the webbing from the D-ring consistent with retractor pretensioner and load limiter deployment (Figure 5). The right-front passenger's frontal airbag has not deployed.

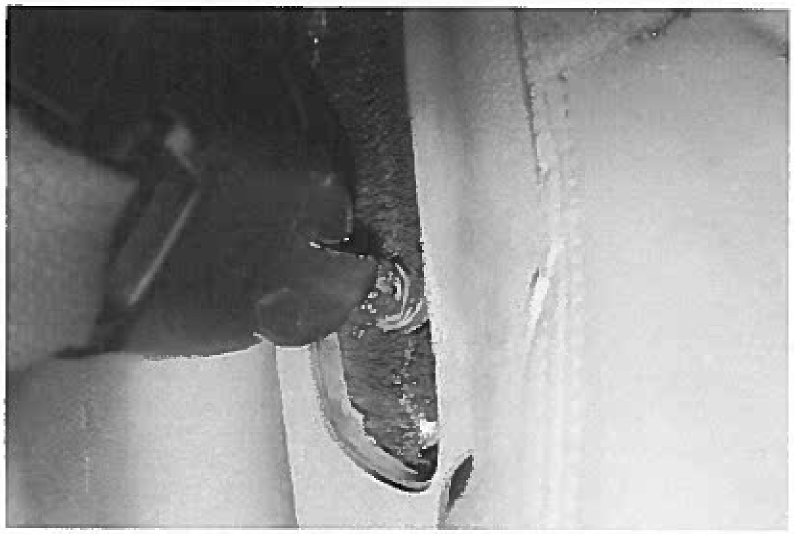


Figure 1: Right-front deployed (retracted) OBA pretensioner

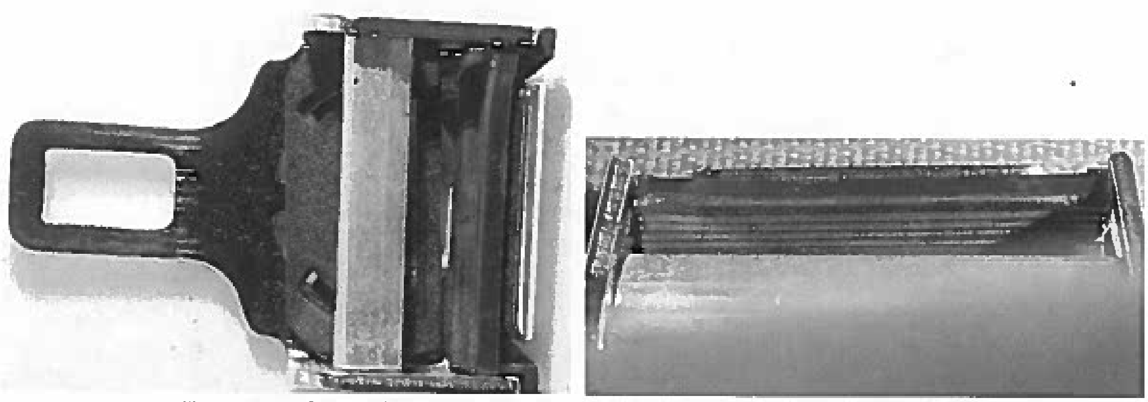


Figure 2a,b: Right-front locking latch plate, and clamping surface

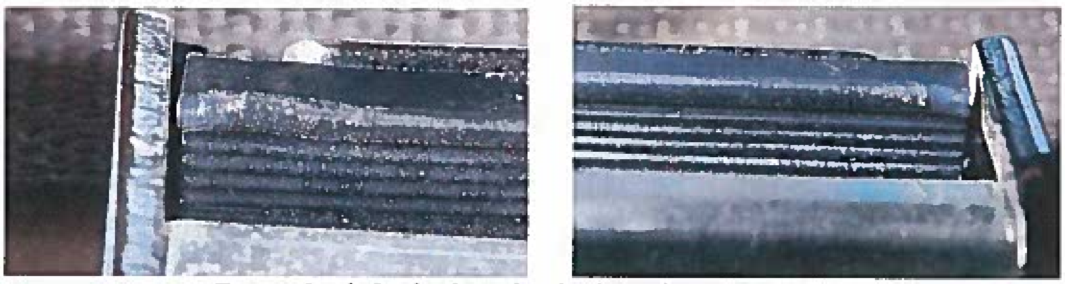


Figure 2c,d: Right-front latch plate clamping surface

Figure 3a,b: Right-front D-ring: inboard and outboard surfaces

Figure 4: Right-front webbing: material deposit

Figure 5: Right-front webbing with plastic transfer from D-ring

SURROGATE STUDY

To better understand the physical evidence on the seat belt, the occupant kinematics and the injuries sustained by K[redacted] F[redacted], on June 22, 2018, my office conducted an exemplar surrogate study with Dr. Elizabeth Raphael. The study was performed using an exemplar 2012 Chevrolet Malibu and a surrogate that was similar in height and weight to K[redacted] F[redacted]. The female surrogate was approximately 4 feet 10 inches tall and weighed approximately 107 pounds. A surrogate for the driver, Ms. Ashley Faust, was also present. The right-front seat was adjusted to the position in which Dr. Raphael and I found the subject right-front seat during our office's vehicle inspections.

When wearing the seat belt properly, the seat belt offered good fit for an occupant the size of K[redacted] F[redacted] (see Figure 6). With the surrogate seated in the right-front seat, the D-ring was approximately 44 inches from the outboard anchor.

Figure 6: Surrogate properly wearing right-front seat belt

The surrogate was also placed in a pre-crash position that was consistent with the physical evidence on the subject seat belt and consistent with [redacted] injuries (see Figure 7). This position is consistent with [redacted] turning and reaching toward the driver position as one might do to alert the driver. When the surrogate did this, the belt moved off her shoulder and onto her upper arm, and the D-ring was approximately 49 inches from the outboard anchor. Based on the physical evidence on the seat belt as well as the expected function of the pretensioners, this location is consistent with the approximate location of the D-ring along the webbing at the time that the pretensioners deployed early in the crash pulse. Based on the physical evidence [redacted] therefore had additional webbing in the seat belt system (as compared to a properly belted occupant), and Figure 7 illustrates one position consistent with this evidence.

Note that during the surrogate study, the origin of the webbing measurements was 4 inches inboard of the outboard anchor. Therefore, the distance from the outboard anchor is 4 inches greater than the measurement indicated by the tape measure in the photographs in Figures 6 and 7.

Figure 7: Surrogate with D-ring at approximately 49 inches

PLAINTIFF'S CLAIMS

Mr. Neil Hannemann states that the seat belt should have been equipped either with a load limiter with a stop (limiting webbing deployment to 6 inches), an adaptive load limiter or a load limiter with a higher deployment threshold.

Mr. Hannemann and Dr. Mariusz Ziejewski opine that [redacted] was properly wearing her seat belt at the start of the subject crash, but do not explain their basis for this. Dr. Ziejewski asserts that [redacted] slipped the shoulder belt webbing, and points to marks on the webbing that he attributes to loading by the latch plate. However, the characteristics of these marks appear to consist of deposits of material and are not from interaction with, or loading from the locking latch plate. In fact, these marks appear to include the deposit of biological material, which may be consistent with a substance such as vomit, or other such material.

Dr. Ziejewski refers to a 2013 Volvo XC60 test as part of the basis for how the seat belt functioned in the subject crash; however, among many differences, this test was obviously a different vehicle, with a different seat belt system, a dummy different in size than [redacted], with a different crash speed and different resulting crash dynamics. Therefore, the referenced Volvo XC60 test is not relevant to the discussion of the performance of the seat belt in the subject crash. These criticisms appear to relate to GM's design specifications rather than the design of Autoliv's components and Autoliv's compliance with these specifications.

FEDERAL MOTOR VEHICLE SAFETY STANDARD (FMVSS) TESTING

For over 50 years, the United States Department of Transportation (DOT) has worked to ensure that "that the public is protected against unreasonable risk of accidents occurring as a result of the design, construction or performance of motor vehicles and is also protected against unreasonable risk of death or injury to persons in the event accidents do occur."[1] This is the responsibility of the National Highway Traffic Safety Administration (NHTSA), a division of the DOT. To this end, NHTSA developed numerous Federal Motor Vehicle Safety Standards (FMVSSs) with which all U.S.-sold passenger vehicles must comply. Vehicles that comply with these FMVSSs have been shown to be highly effective in reducing the likelihood of serious injuries and fatalities in reasonably-foreseeable motor vehicle accidents. Any suggestion that the FMVSSs are minimally effective in protecting occupants from injury or death is unfounded and misleading. The FMVSSs consist of a set of specified tests that, generally speaking, evaluate the vehicle or its components relative to design and performance requirements. FMVSS 208 consists of a suite of tests that evaluates, among other things, driver and right-front passenger belted and unbelted performance in frontal collisions. FMVSS 209 consists of tests and requirements for all vehicle seat belt assemblies at the component level. FMVSS 210 evaluates the integrity of all seat belt anchorages in a vehicle.

The Chevrolet Malibu has been thoroughly tested to ensure compliance with the FMVSSs, including dozens of tests to evaluate the performance of the right-front occupant protection system. Full barrier tests have been conducted to demonstrate effective occupant protection in frontal collisions at 0 degrees, 30 degrees to the left (barrier rotated counterclockwise as viewed from above), and 30 degrees to the right. The Malibu was certified to the requirements of the FMVSS 208 "Advanced Airbag" rulemaking, which requires airbags to be suppressed (not deploy) under certain conditions. Per the requirements of the Advanced Airbag rulemaking, the 2012 Malibu was tested in a number of test modes, including 25 mph offset deformable barrier (ODB), 30 mph flat and angled barriers, and 35 mph frontal barrier. Additionally, per materials produced by General Motors, the vehicle was tested well beyond these requirements.

The 2012 Chevrolet Malibu right-front seat belt complies with all applicable FMVSSs. Materials produced by General Motors and Autoliv show that the seat belts meet or exceed the relevant requirements of FMVSS 208 and FMVSS 209. Per materials produced by General Motors, the occupant restraint system, including but not limited to the vehicle's seat belts, meets or exceeds the requirements of FMVSS 208.

NCAP TESTING

In addition to the FMVSSs that are developed and enforced by NHTSA, there are additional crash tests that are routinely conducted by NHTSA, the auto manufacturers and other organizations to help ensure that U.S. passenger vehicles provide a high level of occupant

[1] (1966) "Preamble to FMVSS." US Congress Public Law 89-563.

protection even in severe collisions. The most common tests conducted are the New Car Assessment Program (NCAP) tests conducted by NHTSA and the auto manufacturers, as well as the Insurance Institute for Highway Safety (IIHS) tests.

The body of testing described above shows that the subject seat and seat belt are effective in reducing the likelihood of injury or death even in severe collisions. The data from these tests show good results for the head (HIC), chest (chest accelerations) and lower extremities (femur loads).

NHTSA has explicitly stated that seat belts are the primary means of occupant restraint in motor vehicle accidents. The effectiveness of seat belts in all types of motor vehicle accidents is well documented. Airbags have always been intended as supplemental restraint systems to offer incremental improvements in restraint effectiveness, even with new rulemakings. Airbags are explicitly labeled as such, both on the vehicle trim ("SRS"), as well as in the owner's manual. When Mr. Hannemann argues that airbags are no longer supplemental, he is ignoring the primary role that seat belts play in occupant restraint.

DISCUSSION

Kinematics and Injuries

Based on her injury analysis, as well as the dynamics of the vehicle crash, Dr. Raphael has determined that [redacted] [redacted] must have been leaning towards her left side when the subject crash began (when the vehicle contacted the tree). Based upon the surrogate study, this would have moved the shoulder belt off of [redacted]'s shoulder and onto her upper arm. This extracted approximately 5 inches of additional webbing from the retractor and positioned the D-ring in a location along the webbing, that is consistent with the physical evidence at the time that the pretensioners deployed, early in the crash pulse.

Seat Belt Physical Evidence

The literature contains numerous examples of how engineering analysis of seat belt marks can be used to reliably determine if and how a seat belt was worn and how the seat belt performed in a collision.[2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17] I have published a peer-reviewed paper looking at this

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[2] (1977) Adomeit, D. et al. "Expected Belt Specific Injury Patterns Dependent on the Angle of Impact." 3rd International Conference on Impact Trauma.
[3] (1984) Moffatt, C. et al. "Diagnosis of Seat Belt Usage in Accidents." SAE 840396.
[4] (1990) Cromack, J. et al. "Occupant Kinematics & Belt Tests with Unrestrained and Partially Restrained Test Dummies." AAAM.
[5] (1990) Gorski, Z. et al. "Examination and Analysis of Seat Belt Loading Marks." Journal of Forensic Sciences 1990 Jan,35(1):69-79.
[6] (1999) Bready, J. et al. "Seat Belt Survey: Identification and Assessment of Noncollision Markings." SAE 1999-01-0441.
[7] (2000) Bready, J. "Characteristics of Seat Belt Restraint System Markings." SAE 2000-01-1317.
[8] (2006) Tanner, C. et al. "Automotive Restraint Loading Evidence for Moderate Speed Impacts and a Variety of Restraint Conditions." SAE 2006-01-0900.

subject.[18] When the webbing moves over a plastic surface (like a latch plate or D-ring) with sufficient speed and force, the plastic softens, and is pushed in the direction of loading and webbing movement. When the webbing movement reverses direction, multiple loading events may be detected on the latch plate or D-ring. The marks on the webbing from the D-ring show that [redacted] was likely out-of-position at the time that the subject crash began, likely leaning toward the driver, with the shoulder portion of the webbing on her upper arm.

With a locking latch plate of the type used as part of the subject seat belt, there would be only a very small length of webbing passing through at the latch plate (between the lap and shoulder sections). Lack of transfer from the latch plate is consistent with minimal pass through of webbing, during the deployment of the pretensioners, as well as during occupant loading in the collision. The marks circled by Dr. Ziejewski in Figure 17[19] in his report are not consistent with those created by a locking latch plate. And, as mentioned above, these marks appear to include the deposit of biological material.

The Role of the Component Supplier

Modern vehicles are typically designed with a number of companies (typically referred to as suppliers) assisting with the design, testing and production of individual vehicle components and systems. With respect to vehicle occupant restraints, typically the vehicle manufacturer provides specifications to suppliers. These specifications include complying with federal regulations (FMVSSs) and may include complying with international regulations (such as European ECE regulations) and may include internal vehicle manufacturer specifications. Specifications typically include, but are not limited to, requirements regarding webbing elongation, pretensioners, load limiters, and airbag modules. Typically, the vehicle manufacturer designs the overall vehicle and integrates the components and systems that are provided by their suppliers. The integration of these components and systems includes both

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[9] (2006) Davee, D. et al. "Case Study of Clothing Fabric Transfer to Seat Belt Webbing Under Accident Forces." SAE 2006-01-0904.
[10] (2006) Raymond, D. et al. "Forensic Determination of Seat Belt Usage in Automotive Collisions: Development of a Diagnostic Tool." SAE 2006-01-1128.
[11] (2006) Toomey, D. et al. "Safety Restraint System Physical Evidence and Biomechanical Injury Potential Due to Belt Entanglement." SAE 2006-01-1670.
[12] (2007) Welsh, K. et al. "Restraint System Markings and Occupant Kinematics in Crash Tests with Disabled Seat Belt Restraint Systems." ASME.
[13] (2008) Heydinger, G. et al. "Comparison of Collision and Noncollision Marks on Vehicle Restraint Systems." SAE 2008-01-0160.
[14] (2009) Jenkins, J. et al. "Forensic Analysis of Seat Belt Retractor Torsion Bars." SAE 2009-01-1242
[15] (2009) Brown, J. et al. "Comparison of Restraint System Marks with Proper and Improper Belt Usage." SAE 2009-01-1243.
[16] (2009) Jakstis, M. et al. "Marks on Seat Belt Systems with Pretensioners and Force Limiters in Airbag Deployment Crashes." SAE 2009-01-1252.
[17] (2011) Hinger, J. "Methods for Evaluating Occupant Kinematics and Seatbelt Use During a Collision." ASME IMECE2011-64736.
[18] (2009) Burnett, R. et al. "Frontal Impact Rear Seatbelt Load Marks: An In-depth Analysis." SAE 2009-01-1249.
[19] Mariusz Ziejewski Report June 20, 2018, p18

mechanical and electrical interfaces. The vehicle manufacturer typically tests and evaluates the performance of the overall vehicle including these components and systems. The occupant protection system consists of multiple subsystems. The seat belt assembly is designed to work in conjunction with the airbag, as well as the vehicle seat and vehicle structures in providing occupant restraint in motor vehicle accidents. This is a reasonable design concept; the supplier often does not know the overall occupant protection design strategy of the vehicle manufacturer.

The file materials that I have reviewed indicate that the development of the seat belt component specifications for the subject seat belt is consistent with the process discussed above. General Motors set performance targets for the occupant protection system and prepared specifications for the airbag and seat belt assemblies. Autoliv provided a seat belt that complied with General Motors' specifications. If General Motors had specified a different torsion bar rating, Autoliv would have supplied that specified design.

In his report, Mr. Hannemann incorrectly refers to Autoliv as the "restraint system manufacturer." [20] This is incorrect; indeed Mr. Hannemann contradicts this just a few paragraphs earlier: he defines the restraint system as "**a system that includes many components**, which cannot be viewed in isolation. Specifically, **some** of these components comprising the restraint system in the subject vehicle are: The seat with occupant classification system, airbag, safety belt system (which has further components affecting system performance), knee bolster and instrument panel (emphasis added)."[21] Autoliv, while indeed supplying the 2012 Malibu seat belt and airbag, was not the "restraint system manufacturer."

Mr. Hannemann has provided no opinion or data that the seat belt functioned other than as specified by General Motors, and as manufactured by Autoliv. He has identified no defect in the seat belt assembly or in the airbag module.

Autoliv provided the seat belt and the right front passenger airbag module, but did not provide General Motors either the hardware (the sensing and diagnostic module (SDM)) nor the software (the algorithm) that ultimately controls the deployment of the right-front passenger airbag module. There is no indication that there is a defect with the right front airbag module.

The Subject Seat Belt and Accident

According to the reconstruction of Mr. Jon Bready, the subject vehicle had a delta-V of approximately 64 mph and a PDOF of 11:30 to 12:00. A delta-V of 64 mph is greater than 99.9% of frontal tow-away crashes in the US.[22, 23]

[20] Neil Hannemann June 20, 2018 report, p13
[21] Ibid Hannemann, p 13
[22] NASS-CDS data
[23] (2010) Goertz, A. et al. "Accident Statistical Distributions From NASS CDS." SAE 2010-01-0139.

The Malibu was designed to, and does comply with the Advanced Airbag portion of FMVSS 208. NHTSA also conducts crash tests at 35 mph as part of their consumer metric New Car Assessment Program (NCAP). No occupant restraint system can prevent all injuries in all crashes. Unfortunately, thousands of people are killed, and hundreds of thousands are seriously injured in motor vehicle crashes every year, including belted occupants[24]. Some crashes exceed the technological limits of what motor vehicle occupant restraint systems are capable of providing, due to the biological limits of the human body.

The subject Chevrolet Malibu's right-front passenger seat belt assembly contains a load limiter, a retractor equipped with a pretensioner and a second pretensioner located on the outboard anchor. The pretensioners are designed to increase the initial tension in the seat belt system at the beginning of the crash event. Contrary to Mr. Hannemann's and Dr. Ziejewski's assertions in their reports, pretensioners are not designed to remove all slack in the seat belt. The load limiter uses a torsion bar constructed of an alloy that is designed to deform plastically, allowing webbing to be deployed under load in a controlled manner. This controlled deployment of webbing under load absorbs substantial energy, while at the same time limiting the seat belt loads applied to the occupant.

The physical evidence (including the marks on the seat belt and the injuries) clearly indicates that [redacted] was wearing her seat belt in the subject crash, but that she was out of position at the beginning of the crash. Before the crash, she appears to have moved to her left and towards the driver, likely allowing the seat belt to move onto her arm. During my vehicle and seat belt inspections, I documented a mark on the webbing (plastic transfer) that was approximately 10 inches long. The nature of this mark is typical of the type of the mark that is created when a load limiter deploys.

My analysis confirms that the seat belt retractor performance was consistent with the retractor and load limiter functioning appropriately in the subject crash. The retractor locked and remained locked. The torsion bar deformed in a controlled manner as designed.[25]

Moreover, my review of the file confirms that the subject Chevrolet Malibu complied with the applicable federal regulations. For the seat belt, this compliance was confirmed not just by Autoliv, but by a third-party laboratory, SGS.

In order to compare the amount of webbing that is deployed by load limiters of different vehicle designs, I reviewed the NHTSA testing database and plotted the shoulder belt extension that was measured for the right-front seating position during NCAP tests. This data was not measured in all tests, but was collected in more than 100 tests. As can be seen in Figure 8, there is a wide range in the amount of webbing deployed by the load limiter (red bar indicates webbing deployed by load limiter; blue bar indicates retraction by a pretensioner). A large number of vehicles perform well in standardized testing even when the load limiters

[24] NHTSA Traffic Safety Facts, 2012
[25] (2009) Jenkins, J. et al. "Forensic Analysis of Seat Belt Retractor Torsion Bars." SAE 2009-01-1242.

deploy as much, or more, webbing than the Malibu load limiter. In the subject collision, the front passenger seat belt functioned appropriately.

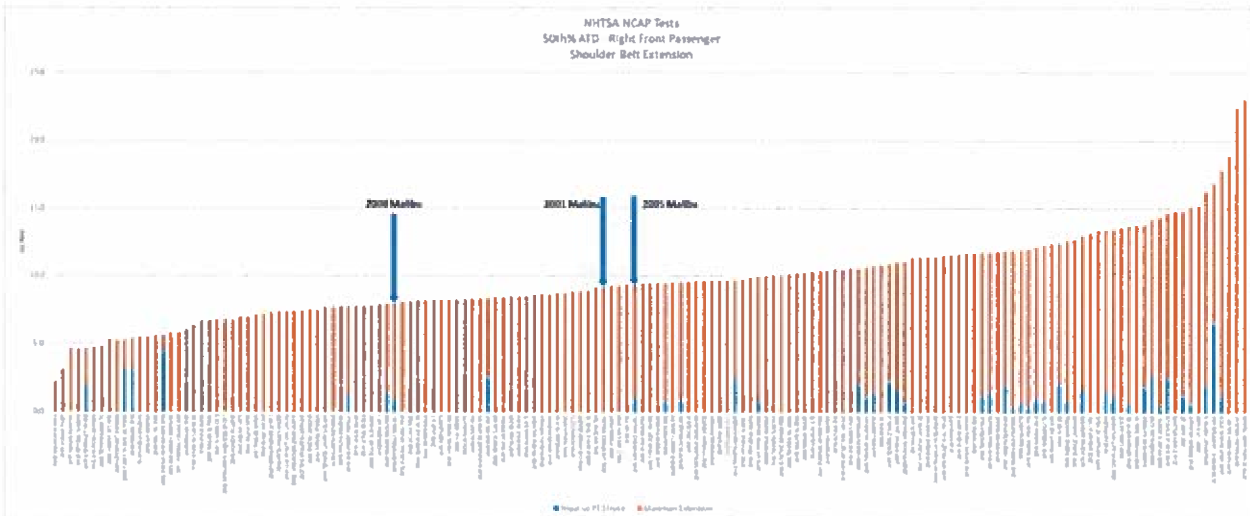


Figure 8: Right-front shoulder belt extension in NCAP tests (Appendix B contains a higher resolution version of this figure)

<u>Seat Belt & Load limiter</u>

As discussed above, the subject Chevrolet Malibu right-front passenger seat belt assembly contains both pretensioners and a load limiter. The pretensioner is designed to tighten the lap and shoulder belts early in the crash event. A load-limiting torsion bar is part of the energy management system of the occupant restraint system. The torsion bar is constructed of an alloy that is designed to deform plastically, allowing webbing, when under load, to be deployed in a controlled manner. This controlled, gradual deployment of webbing is designed to restrain the occupant and absorb crash energy while limiting the force applied to the chest. There is extensive literature documenting the ability of load limiters to effectively manage energy in crash events to help reduce the risk of injury.

As stated above, my analysis of the physical evidence indicates that the right-front load limiter deployed approximately 10 inches of webbing. This performance is expected and is consistent with the design of the load limiter.

Mr. Hannemann (as well as Dr. Ziejewski) repeatedly uses the word "slack" to describe the webbing that is deployed from the load limiter. This is incorrect and misleading as the webbing is not 'slack', but deploying under a carefully controlled load of hundreds of pounds and absorbing hundreds of foot-pounds of energy.

Mr. Hannemann also states that load limiters were incorporated to achieve better NCAP ratings. This implies that load limiters are used solely to achieve better ratings; I am aware of no testimony or data that supports this position. He also does not acknowledge that, in general, better NCAP ratings are associated with lower injury risk. As additional technologies are developed, the OEMs add new features (increase the technological content) to their occupant restraint systems. This is done in order to incrementally improve the performance of their occupant protection systems, both in standardized tests and in real world collisions.

Mr. Hannemann appears to discount the well-established benefits of energy management and load limiting that are provided by a torsion bar. A torsion bar is carefully designed and manufactured to deploy the webbing in a controlled fashion under relatively constant load as it absorbs crash energy and allows the occupant to ride down the crash, while reducing the force to the chest and reducing the risk of injury. Relatively light marks on the latch plate, with no clear latch-plate marks on the webbing, show that at most only a small amount of webbing was allowed to pass through the latch plate between the shoulder portion and the lap portion of the seat belt. Mr. Hannemann states the "dangers of load-limiters include excessive excursion, which can result in contact with the interior components. Excessive belt slack can also cause the safety belt to slip off the iliac crest." Again, the use of the word "slack" in relation to the function of a load limiter implies Mr. Hannemann completely misunderstands how a load limiter operates. In addition, there is no evidence this happened in the subject crash, or that any excess webbing was in the lap belt.

NHTSA has tested hundreds of seat belts as part of their FMVSS 209 compliance program[26], including seat belts with load-limiters. To my knowledge, NHTSA has never noted an issue or defect in either these audit tests or in NHTSA full-scale vehicle testing (FMVSS 208 and/or NCAP) due to "excessive excursion" of load-limiter payout.

It can be seen that a portion of the webbing that was pulled forcefully over the D-ring had partially retracted back over the D-ring (Figure 9a, 9b). This is likely due in part to relaxation of the elastic stretch of the webbing. Even if the retractor had been equipped with a load limiter that had a 6-inch "stop," or a higher-threshold torsion bar, the webbing would still be designed to stretch in order to help manage occupant ride-down energy.

[26] https://icsw.nhtsa.gov/cars/problems/comply/index.cfm

Figure 9a, b: Webbing with load limiter marks on both sides of D-ring

If K[redacted] F[redacted]'s seat belt had not been equipped with a torsion bar, and equipped with the upper limit of compliant webbing as allowed by FMVSS 209, the resulting occupant excursion could be equal to or greater than the occupant excursion experienced with the load limiter and stiffer webbing that was used in the 2012 Malibu.

Mr. Hannemann proposed alternative designs that use stops to limit the amount of webbing that is allowed to deploy from the load limiter. However, he has not performed or produced testing that would confirm his hypothesis that the presence of these technologies would have changed K[redacted] F[redacted]'s outcome. Neither Mr. Hannemann nor Dr. Ziejewski discusses the effect that such stops would have on the forces applied to the body, or how these increased forces would increase the risk of injury. Increasing the deployment threshold of the torsion bar, or incorporating a stop, would be expected to increase the loads on Miss Faust's chest in the subject crash.

Mr. Hannemann and Dr. Ziejewski criticize the 2012 Malibu right-front seat belt design for incorporating a 2-kN torsion bar. Dr. Ziejewski opines that if K[redacted] F[redacted] had been offered either a 5-kN torsion bar, or with the load limiter that limited the deployment to 6 inches, that this "would have kept Ms. K[redacted] F[redacted] within the safe confines of her seat."[27] Neither Mr. Hannemann nor Dr. Ziejewski calculates or quantifies the occupant excursion that would have occurred had the subject vehicle been equipped with these alternative designs. They imply, but do not prove, that the difference in excursion between these designs would be about 3 ½ inches. They do not explain why reducing excursion by 3 ½ inches would have made a difference in K[redacted] F[redacted]'s outcome. And, as mentioned earlier, they do not acknowledge or discuss the increase in chest loads that would result from a stiffer load limiter deployment threshold or a stop, and the fact that these increased chest loads would increase the risk of some types of injuries.

[27] Mariusz Ziejewski Report June 20, 2018, p20

Mr. Hannemann also states that one of his alternative technologies is "adaptive load limiters." Although he did not describe what he was referring to precisely, adaptive load limiters typically have deployment thresholds that either increase or decrease as additional webbing is deployed. However, he offers no details whatsoever on what specifications he would recommend for an adaptive load limiter. Adaptive load limiters encompass a wide range of design options, and it is not at all clear what Mr. Hannemann recommends, or how he has established that this would be effective for [redacted] and for the wide range of other occupants for whom this seat belt must be designed.

Again, it appears that neither Mr. Hannemann nor Dr. Ziejewski has run any sort of test with Mr. Hannemann's alternative seat belt designs to establish the effect of these technologies on [redacted]'s outcome. Nor have they conducted tests to show what effect these technologies would have for the wide range of test conditions and occupants that should be considered before making a design change of this type.

Mr. Hannemann refers to a paper by IIHS that studied load limiters, but this paper is not directly applicable to the 2012 Malibu or the subject collision scenario. The IIHS paper only looked at vehicles with depowered airbags, with and without load limiters. The subject 2012 Malibu was designed with advanced, dual-stage airbags. This paper also looked at a limited number of "sample" cases from the NASS-CDS database. For these sample cases involving multiple impacts or offset loading, the author seems to suggest that there was excessive excursion or payout of the seat belt. Per the reconstruction of Mr. Bready, the subject crash was not an offset collision and did not involve multiple impacts with other vehicles. Additionally, only one of the cases contained in the paper involved a right-front passenger, and the author acknowledges that there was "possible seat movement" involved in the crash.

Literature and data collected by NHTSA, as well as other researchers, show that fatalities and injuries in motor vehicle accidents have been generally decreasing in both absolute and relative numbers. This reduction in injuries and fatalities is due, in part, to improvements in occupant restraint systems, including the introduction of advanced technologies such as load limiters. For both model year 2012, and the current model year, the vast majority of vehicles have load limiters for the front-outboard seating positions. There is extensive literature documenting the efficacy of load limiters as a technology that effectively manages energy in crash events, and reduces the risk of injury.[28,29,30,31,32,33]

[28] (2003) Walz, M. "NCAP Test Improvements with Pretensioners and Load-limiters." NHTSA DOT HS 809 562.
[29] (2004) Kahane, C. "Lives Saved By the Federal Motor Vehicle Safety Standards and Other Vehicle Safety Technologies, 1960-2002." NHTSA DOT HS 809 833.
[30] (2009) Sohr, S. et al. "Benefit of Adaptive Occupant Restraint Systems with Focus on the New US-NCAP Rating Requirements." ESV 09-0322.
[31] (2011) Lange, R. et al. "Installation Patterns for Emerging Injury Mitigation Technologies." ESV 11-0088-O.
[32] (2013) Kahane, C. "Effectiveness of Pretensioners and Load-limiters for Enhancing Fatality Reduction By Seat Belts." NHTSA DOT HS 811 835.
[33] (2015) Kahane, C. "Lives Saved By Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012. NHTSA DOT HS 812 069.

NHTSA has also concluded on a number of occasions, most recently in 2013, that technologies like pretensioners and load limiters have a positive effect on vehicle safety. From a 2013 NHTSA report, for "passenger cars, CUVs, and minivans, a belted driver or right-front passenger has an estimated 12.8 percent lower fatality risk if the belt is equipped with a pretensioner and a load-limiter than if it is not equipped with either."

I have conducted testing and published a peer-reviewed paper on the utilization of load limiters, establishing their effectiveness for occupant protection, and that they are but one component of a multifaceted occupant protection system. The specification of the torsion bar alone is not predictive of outcome:[34]

> *"Research presented in this paper shows that because load limiters are just one component of a multi-component occupant protection system, the performance of the overall occupant protection system cannot be predicted from the load limiter performance or specifications alone. The overall occupant protection system is designed such that the load limiter works in conjunction with the webbing stiffness, airbag, vehicle interior surfaces and vehicle structure to provide effective occupant protection. My paper established that effective occupant protection has been achieved using different combinations of these parameters."*

I have reviewed various NCAP tests and assessed the shoulder belt loads, the amount of webbing deployed from the retractor, and ATD injury metrics. While there is published data that shows that vehicles that are equipped with load limiters and pretensioners improve the overall effectiveness of occupant protection systems,[35] I am aware of no study that shows a direct relationship between the characteristics of load limiters (such as deployment thresholds) and the effectiveness of the overall occupant protection system. As stated previously, the retractor is one part of a complex system that provides occupant protection.

REVIEW OF PEER VEHICLE DESIGNS

As discussed in my paper, I have looked at load limiter designs utilized in other vehicles. There is a wide range of load limiter deployment thresholds used as part of the overall occupant protection system (Figure 10)[36]. All of these occupant protection systems are designed to offer occupant restraint to a wide variety of occupants, and under a broad range of crash forces.

[34] (2016) Van Arsdell, W. et al. "Load-limiters Effect on Occupant Restraint Systems." SAE 2016-01-1505.
[35] Ibid, (2013) Kahane, C.
[36] (2016) Van Arsdell, W.

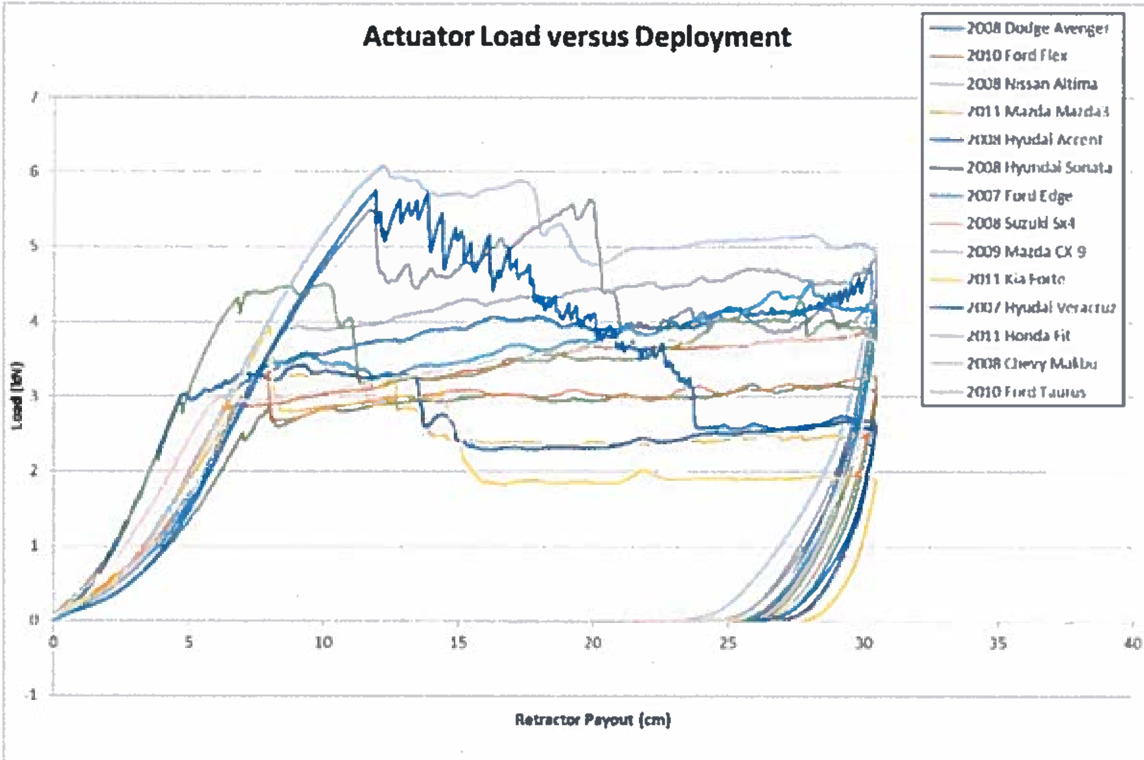


Figure 10: Deployment thresholds

SUMMARY OF KEY CONCLUSIONS

Based on my background and experience in the areas of mechanical engineering and occupant restraint systems, and the materials reviewed to date, I have formed the above (contained in the body of this report) and following opinions to a reasonable degree of engineering certainty. As additional information becomes available, it may be necessary to continue my investigation and supplement or modify my opinions and conclusions.

1. The 2012 Chevrolet Malibu right-front seat belt assembly is appropriately designed and manufactured.
2. The 2012 Chevrolet Malibu right-front seat belt assembly meets or exceeds all relevant FMVSSs.
3. Autoliv produced the subject seat belt in accordance to design guidelines set by General Motors for this vehicle.
4. The subject seat belt design is not defective or unreasonably dangerous.
5. The subject seat belt functioned as designed in the subject crash.

6. Based on the physical evidence, and consultation with Dr. Elizabeth Raphael, [redacted] likely pre-positioned herself immediately before the crash, such that the seat belt moved off of her shoulder and onto her upper arm.

7. No evidence or testing has been produced that would support the proposition that Mr. Hannemann's alternative designs would have made a difference in [redacted]'s outcome in the subject crash.

8. Seat belts which meet the requirements of FMVSS 208 and FMVSS 209 have been shown to be effective in reducing injuries and fatalities in reasonably-foreseeable motor vehicle accidents.

9. Autoliv conducted a reasonable amount of testing in the design and development of the seat belt assembly and airbag module for the subject vehicle.

10. The non-deployment of the right-front passenger airbag in the subject crash does not make the design or performance of the right-front seat belt defective.

11. Autoliv provided the right-front airbag module but not the sensing and diagnostic module (SDM). The SDM determines if a deployment signal should be sent to the airbag module. From the EDR report, it is clear that the SDM did not send a deployment signal to the right-front airbag in this collision. There is no indication that there is a defect with the right-front airbag module.

12. The subject motor vehicle collision was more severe than about 99.9% of all frontal collisions that occur in the United States.

13. No seat belt or restraint system can protect all occupants from all injuries in all crashes.

Sincerely,

William W. Van Arsdell, Ph.D., P.E.
Principal Engineer
Enclosures

Appendix A: Materials Reviewed

1. Court Documents:
    a. Petition
    b. 1st Amended Petition
    c. Plaintiffs' Response To The First Set Of Interrogatories And Requests For Production Of Documents From Defendant, General Motors LLC
    d. Notice of Removal
    e. Plaintiffs' Resp to Autoliv 1st RFPs
    f. Plaintiffs' Resp to Autoliv 1st Rogs
    g. Autoliv Initial Disclosures, 2.6.17
    h. GM Initial Disclosures
    i. Plaintiffs' Initial Disclosures
    j. Amended Scheduling Order
    k. Pltf's 1st Amended Notice
    l. 2nd Amended Scheduling order Rec 11Dec17
    m. Amended Protective Order
    n. Pltfs' Expert Disclosures

2. First Responder Reports:
    a. OCPD Collision Report 031714
    b. OCPD2014-0021174 911 call
    c. OKCFD 14-014339 EMS Redacted
    d. OKCFD 14-014339 CAD Report Redacted
    e. OKCFD 14-014339 NFIRS
    f. OKCFD 602 (screenshot)
    g. OKCFD Sta. 18 (notes)
    h. OKCFD Sta. 27 (notes)

3. Photographs and Video:
    a. Bob Smart Accident Photos, taken 11/13/16 (24 color photos)
    b. Ashley & K[redacted] Facebook Photo
    c. Seatbelt Photos – taken 8/17/16 (20 color photos)
    d. Photos and Video of K[redacted] in the hospital, and funeral
    e. OKCPD Photographs (71 color photos)
    f. EP Vehicle Inspection Photographs,
    g. Elizabeth Raphael Veh. Insp. Photos
    h. CSE Faust Vehicle Inspection
    i. EP/Delta-V Surrogate Study Photographs, June 22, 2018
    j. Wright (Battalion Chief) email with photos

4. Expert Reports and Materials
    a. Hannemann, Neil, dated June 20, 2018
    b. Munsell, William, dated June 20,2018
    c. Ziejewski, Mariusz, dated June 20, 2018

5. Depositions and Exhibits of:
    a. Faust, Ashley
    b. Faust, Jill

c. Faust, Richard
d. Frederick, Justin
e. Kelly, Trevor
f. Kiihr, Elizabeth
g. Lewis, Samuel
h. Paige, Dennis
i. Prentkowski, David
j. Sadrnia, Hamed
k. Scruggs, William
l. Smith, Joe
m. Spence, Scotty
n. Spencer, Tori
o. Stark, Eric

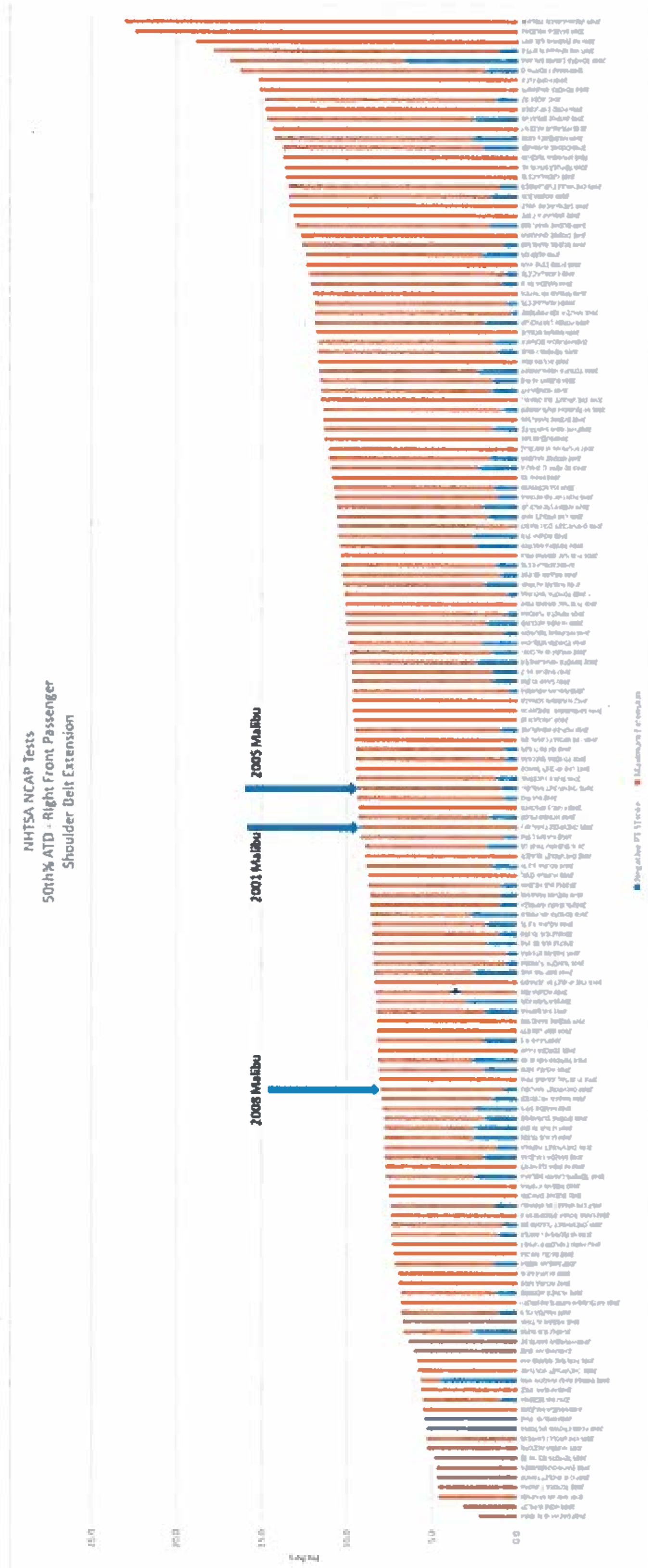
6. Production – Subject to Protective Order:
   a. Combined Plaintiff Production (Bates 1 - 160)
   b. Supplemental Response to RFP 10
   c. Autoliv Production
   d. GM Document Production

7. Medical Records from:
   a. Ashley - Combined Medical Bills, Bates No. 161-216
   b. Ashley - Combined Medical Records from 3-17-2014 to Present, Bates No. 217-827
   c. Ashley - Pre-3-17-2014, Bates No. 828-852
   d. K[redacted]- Combined Records Before accident, Bates No. 853-867
   e. K[redacted]-Combined related medical records & bills. Bates No. 868-1687
   f. Radiology
   g. Medical Examiner Report
   h. Autopsy Report

8. Media Coverage:
   a. KOCO - Preteen Choctaw Cheerleader Dies (Article and Videos)

9. Miscellaneous:
   a. CDR Download
   b. Carfax
   c. Faust Residence - Google Earth
   d. Obituary - K[redacted] Faust
   e. Combined Plaintiff Production (Bates 1 - 160)
   f. Death Certificate

Appendix B



NHTSA NCAP Tests
50th% ATD - Right Front Passenger
Shoulder Belt Extension
2005 Malibu
2003 Malibu
2008 Malibu
25.0
20.0
15.0
10.0
5.0
0.0